Journal of World Architecture, 2023, Volume 7, Issue 6
https://ojs.bbwpublisher.com/index.php/JWA
Online ISSN: 2208-3499
Print ISSN: 2208-3480

Assessment and Optimization Strategies of Campus Sound Environment

Cuicui Qin[1]*, Qiliang Yu[1], Wei Zhang[2]

[1]School of Construction Engineering, Shenzhen Polytechnic University, Shenzhen 518000, Guangdong Province, China
[2]Guangdong Province Prefabricated Building Design Institute Co., Ltd., Guangzhou 510000, Guangdong Province, China

Corresponding author: Cuicui Qin, cuicui_qin@sina.com

Abstract: A good sound environment is essential in creating a harmonious and peaceful campus, improving students' learning outcomes, promoting physical and mental health, and creating a green and healthy campus. This study investigated the impact of new buildings on existing ones by optimizing the spacing between new buildings and the sound insulation structure of building enclosures. The results indicated that building 4 was affected by the noise from new building 1 and its surroundings, with a maximum outdoor daytime noise level reaching 69 dB, and the indoor background noise level in the least favorable classroom was 43.73 dB, less than 45 dB, which was within the acceptable range. It is recommended that the sound insulation design be improved in the planning of new teaching buildings. Besides, the surrounding traffic conditions should be improved, and the usage time of sports facilities should be scheduled appropriately to prevent the noise from sporting activities from affecting the classroom activities. The findings of this study provide valuable references for future architectural acoustics design and campus planning, contributing to the creation of peaceful and comfortable campus environments.

Keywords: Green campus; Teaching building; Noise control; Acoustic optimization

Online publication: December 26, 2023

1. Introduction

In developing a green campus, the focus is on managing building acoustics and addressing indoor/outdoor noise. The purpose of optimizing architectural designs is not just for environmental concerns but also for creating a quiet, pleasant learning environment to enhance the overall campus image and quality. The use of eco-friendly materials and soundproof structures serves to reduce noise levels, providing a healthy, comfortable space for students and teachers, which contributes to the sustainable development of the campus.

In the field of academia, research has been conducted on the sound environment of campus buildings both domestically and internationally. However, current research primarily focuses on assessing the buildings' acoustic properties and their impact on the sound environment. For example, Liu explored various methods of sound assessment, influential factors, and related issues in sound environment design [1]. Kim examined the sound quality of buildings with the aim of providing references for sustainable workplace environments [2].

Zannin investigated noise and vibration conditions in residential buildings located near subway lines [3]. Yang conducted a case study on the soundscape in hospital environments in Beijing [4]. Aletta conducted a systematic review and meta-analysis to investigate the relationship between soundscapes and urban regeneration [5]. Lee evaluated noise and vibration conditions in high-rise residential buildings under construction [6]. Bento Coelho explored soundscape design and perception in outdoor sports facilities using a football field as a case study [7]. This paper seeks to support theory and guide practice in enhancing the campus sound environment. However, there is a lack of research regarding the evaluation and optimization of campus sound environments. Hence, this study explores strategies for evaluating and optimizing building sound environments, providing valuable insights to improve the overall campus environment.

2. Research method

2.1. Outdoor noise simulation software

In this study, the architectural sound environment analysis software SEDU was used for simulation and calculation analysis. SEDU is a software that can be used for noise calculation, assessment, and prediction. The software's calculations strictly adhere to the requirements of relevant national standards, and its computational principles are based on the International Organization for Standardization's "Calculation of Outdoor Sound Propagation Attenuation," ISO9613-2:1996, and other standards.

2.2. Indoor background noise calculation principles

The combined wall sound insulation of this project consisted of two components: the external wall and the external window. The total effective sound insulation of the windows and walls in a room was calculated based on the book *Building Physics and Design*. The following equations were applied:

$$R = 10\, lg \frac{1}{\tau} \tag{1}$$

R: Combined effective sound insulation (dB)

τ: Combined transmittance coefficient

$$\tau = \frac{s_1\tau_1 + s_2\tau_2}{s_1 + s_2} \tag{2}$$

τ_1: Window transmittance coefficient

τ_2: External wall transmittance coefficient

S_1: Window area

S_2: External wall area

2.3. Model

The noise from the basketball court and surrounding traffic was also accounted for in this study. By adjusting the campus layout, the distance between the new and existing structures was increased from 5 to 6.5 meters. Additionally, all building envelope structures were upgraded for enhanced sound insulation performance, as illustrated in **Figure 1**. This optimization serves as a valuable reference for future architectural planning and design. In the campus buildings, **Figure 1** indicates that traffic noise was the primary source of outdoor noise. **Table 1** details the noise sources considered in this project's calculation, with vehicle speed and traffic volume data set by the client based on the project's actual conditions.

According to the Chinese standard GB50099-2011 for Design Specification for Primary and Secondary School Buildings [8], the acceptable noise level for reading and singing in classrooms reaching 1 meter outside is around 80 dB. For physical education classes, the acceptable noise level at sports facilities ranges from 70 dB to 75 dB. In this project's simulation, the noise level for the line source at the basketball court's edge was set to 75 dB, and the surface source's noise level 1 meter outside the classroom was set to 80 dB.

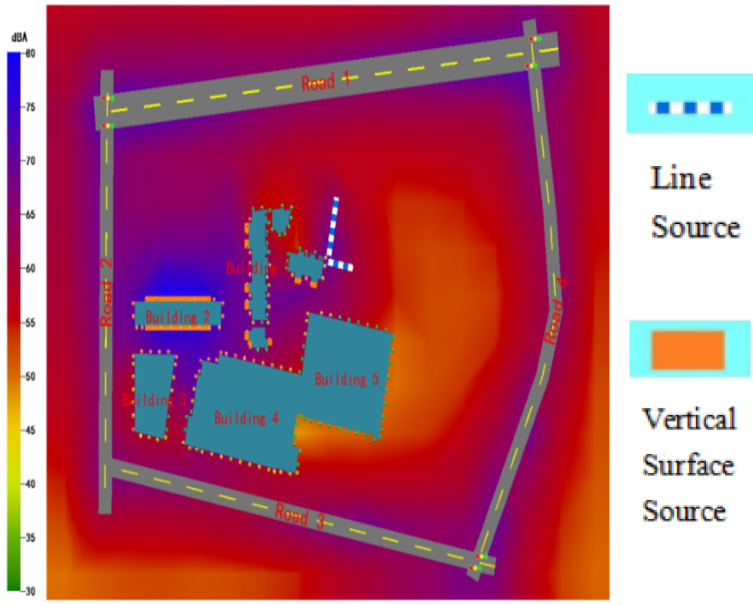

Figure 1. The project model

Table 1. Traffic noise sources

Road	Time period	Design speed (km/h)	Small vehicles		Medium vehicles		Large vehicles	
			Hourly traffic flow	Noise Grade 1 at 7.5 m (dB[A])	Hourly traffic flow	Noise Grade 1 at 7.5 m dB(A)	Hourly traffic flow	Noise Grade 1 at 7.5 m (dB[A])
Road 1	Day	60	400	72	50	72	0	79
Road 2	Day	60	200	72	20	72	0	79
Road 3	Day	60	200	72	20	72	0	79
Road 4	Day	60	200	72	20	72	0	79

2.4. Evaluation criteria

According to the Green Building Evaluation Standard GB-T 50378-2019 [9] and the Design Specification for Sound Insulation in Civil Buildings GB50118-2010 [10], the noise levels in the functional rooms of this project must adhere to the requirement that indoor background noise in classrooms should not exceed 45 dB.

3. Results and discussion

Figure 2 illustrates the site noise distribution through software simulations. Notably, among the classrooms depicted in **Figure 2**, one stood out as the least favorable concerning indoor noise, influenced by outdoor noise in the existing teaching building (Building 4). Its maximum daytime outdoor noise reached 68dB. Hence, this room was chosen as the critical space for indoor background noise calculations. The dimensions of the classrooms, based on the project's floor plan and elevation, are detailed in **Figure 3**.

The perimeter structure of the classrooms included external walls, windows, and beams. The floor height was 3.9 meters, and the beam height was 0.8 meters. The specific indicators are shown in **Table 2** below.

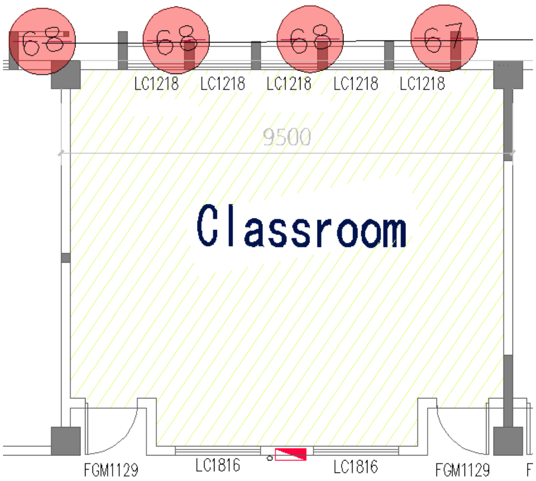

Figure 2. Daytime outdoor noise levels for Building 3

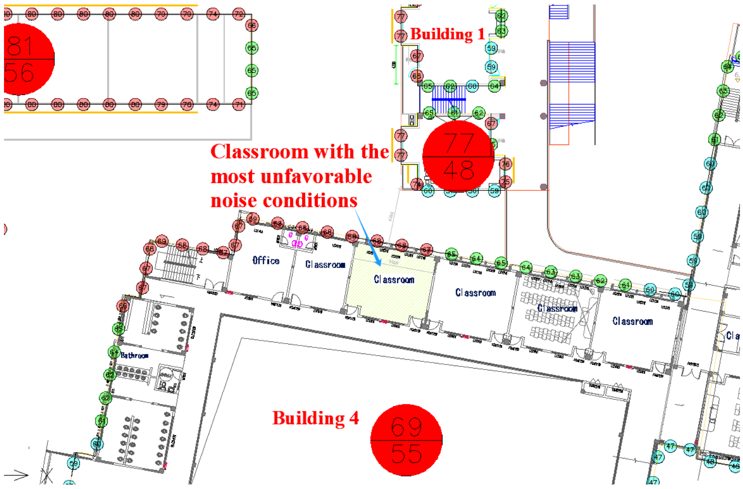

Figure 3. Plan of the least favorable classroom

Table 2. Classroom envelope area

Category	Windows	Beams	Walls	Total area (m^2)
Area (m^2)	10.80	21.60	4.65	37.05

To create a favorable indoor acoustic environment, the sound insulation performance of the building's envelope structure was optimized. The exterior walls were constructed using 200 mm aerated concrete, while the exterior beams and columns were made of reinforced concrete. The external windows were designed with 8mm Low-E + 12mm air gap + 6mm clear glass. According to the "Architectural Sound Insulation and Absorption Structure" Atlas 08J931 [10], the sound insulation of the external walls with aerated concrete is 46dB, the sound insulation of the external walls with reinforced concrete is 52 dB, and the sound insulation of 8 mm Low-E + 12 mm air + 6 mm transparent glass is 29 dB.

According to the sound insulation Equation (2), the combined transmission coefficient of the external wall was $\tau = 0.00037$.

According to the sound insulation Equation (1), the combined sound insulation of the external wall was $R = 34.27$ dB.

Considering the differences in sound insulation of different materials at different frequencies, here, the sound insulation situation was reduced by 10 dB, that is, the effective sound insulation of the combination of walls and windows in this project was 24.27 dB. Therefore, the indoor background noise in a closed-window state was the daytime outdoor noise minus the effective sound insulation of the walls and windows.

The background noise in the classroom was calculated as 68 dB–24.27 dB = 43.73 dB.

4. Conclusion

The acoustic environment in the campus' buildings was thoroughly examined in this study, revealing that the classrooms in Building 4 were impacted by noise from the newly constructed Building 1. Despite outdoor noise levels near Building 1 reaching 68 dB during the day, indoor levels remained below 45 dB when the windows were closed, which is within the acceptable range. Therefore, we suggest strengthening sound insulation in the new teaching building's planning, optimizing traffic flow, and scheduling sports facility usage to maintain a high-quality acoustic environment in existing structures. Overall, the findings provide valuable insights for future campus planning, emphasizing strategies such as optimizing layouts, using natural sound barriers, and promoting noise control awareness for a peaceful and harmonious learning environment.

Funding

The research was supported by the following projects:

(1) Education Research and Reform Projects of Shenzhen Polytechnic University, China (Project No. 7022310092)

(2) 2022 Green Building Design Golden Course Construction Project of Shenzhen Polytechnic University, China

(3) 2023 Guangdong Provincial Education and Teaching Reform Research and Practice Project, China

(4) 2021 College Student Innovation Project of Shenzhen Polytechnic University, China (Project No. P-20210607-39632)

(5) 2023 Education and Teaching Reform Project of the Higher Vocational Civil Engineering and Water Resources Instruction Committee of Guangdong Province, China (Project No. 2023TJSL21)

(6) The Class II Brand Specialty Construction of the Guangdong Province, China (Project No. 9004-02200202)

Disclosure statement

The authors declare no conflict of interest.

References

[1] Liu Y, Kang J, Schulte-Fortkamp B, 2021, A Review on Soundscape in Urban Open Spaces. Building and Environment, 201: 107966.

[2] Kim J, Ryu D, Jeon J, 2021, A Study on the Sound Quality Assessment of Office Buildings for Sustainable Workplace Environments. Sustainability, 13(4): 2060.

[3] Zannin PH, Marconato A, 2021, Assessment of Noise and Vibration in Residential Buildings Located Near Subway Lines. Science of the Total Environment, 751: 141733.

[4] Yang W, Kang J, 2022, Investigation of the Soundscape in Hospital Environments: A Case Study in Beijing. Building Acoustics, 29(1): 41–56.

[5] Aletta F, Kang J, 2022, Soundscape and Urban Regeneration: A Systematic Review and Meta-Analysis. Cities, 120: 103254.

[6] Lee PJ, Jeon JY, 2023, Evaluation of Noise and Vibration in High-Rise Residential Buildings Under Construction. Journal of Environmental Management, 304: 114063.

[7] Bento Coelho JL, Peixoto AP, 2023, Soundscape Design and Perception in Outdoor Sports Facilities: A Case Study on a Soccer Stadium. Journal of Building Engineering, 49: 102514.

[8] Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2011, Design Specification for Primary and Secondary School Buildings, GB50099-2011.

[9] Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2019, Assessment Standard

for Green Building, GB/T 50378-2019.
[10] Ministry of Housing and Urban-Rural Development of the People's Republic of China, Code for Design of Sound Insulation of Civil Buildings, GB50118-2010.